Cryogenic Selective Surfaces

Completed Technology Project (2015 - 2016)

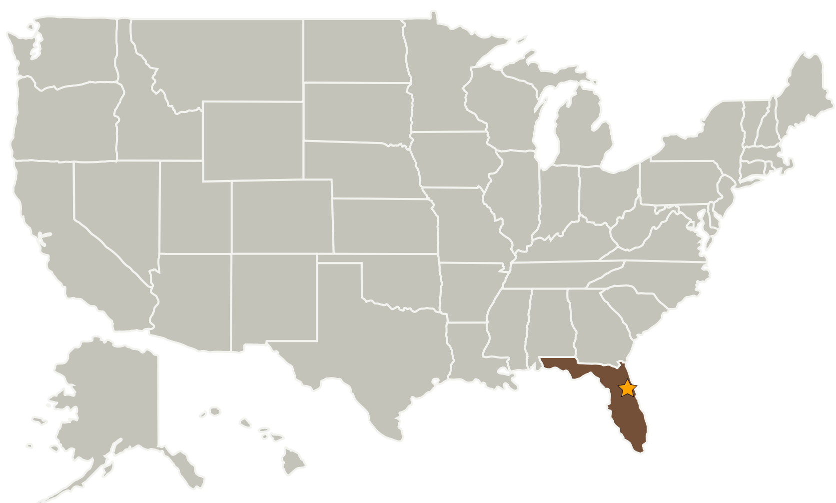
Project Introduction

Selective surfaces have wavelength dependent emissivity/absorption. These surfaces can be designed to reflect solar radiation, while maximizing infrared emittance, yielding a cooling effect even in sunlight. On earth cooling to -50 \xa1C below ambient has been achieved, but in space, outside of the atmosphere, theory using ideal materials has predicted a maximum cooling to 40 K! If this result holds up for real world materials and conditions, then superconducting systems and cryogenic storage can be achieved in space without active cooling. Such a result would enable long term cryogenic storage in deep space and the use of large scale superconducting systems for such applications as galactic cosmic radiation (GCR) shielding and large scale energy storage. We propose, during this Phase I effort, to theoretically model the performance of real world selective surfaces to see if superconducting temperatures can be passively achieved in a deep space environment at 1 A.U. from the sun.

Anticipated Benefits

Such surfaces may allow superconducting wire to operate in deep space or to minimize boil-off in LOX tanks without active cooling.

Primary U.S. Work Locations and Key Partners



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Organizations Performing Work	Role	Type	Location
★Kennedy Space Center(KSC)	Lead Organization	NASA Center	Kennedy Space Center, Florida

Primary U.S. Work Locations
Florida

Project Transitions

July 2015: Project Start

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Center / Facility:

Kennedy Space Center (KSC)

Responsible Program:

NASA Innovative Advanced Concepts

Project Management

Program Director:

Jason E Derleth

Program Manager:

Eric A Eberly

Principal Investigator:

Robert C Youngquist

Co-Investigator:

Mark A Nurge

NASA Innovative Advanced Concepts

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June 2016: Closed out

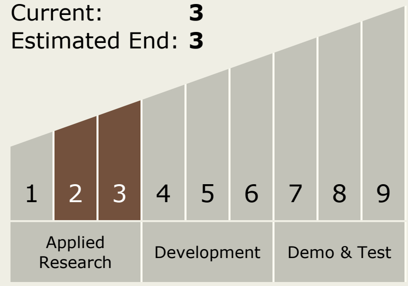
Closeout Summary: There are many challenges involved in deep-space exploration, but several of these can be mitigated, or even solved, by the development of a coating that can reject most of the Sun's energy and yet still provide some far-infrared heat emission. Such a coating would allow non-heat-generating objects in space to reach cryogenic temperatures without using an active cooling system. This would be a benefit to deep-space sensors that require low temperatures, such as the James Webb Telescope focal plane array. It would also allow the use of superconductors in deep space, which could lead to magnetic energy storage rings, lossless power delivery, or perhaps a large-volume magnetic shield against galactic cosmic radiation. But perhaps the most significant enablement achieved from such a coating would be the long-term storage in deep space of cryogenic liquids, such as liquid oxygen (LOX). In this report, we review the state of the art in low-temperature coatings and calculate the lowest temperatures each of these can achieve, demonstrating that cryogenic temperatures cannot be reached in deep space in this fashion. We then propose a new coating that does allow coated objects in deep space to achieve the very low temperatures required to store liquid oxygen or nitrogen. These new coatings consist of a moderately thick scattering layer (typically 5 mm) composed of a material transparent to most of the solar spectrum. This layer acts as a scatterer to the Sun's light, performing the same process as titanium dioxide in white paint in the visible. Under that layer, we place a metallic reflector, e.g. silver, to reflect long-wave radiation that is not well scattered. The result is a coating we call Solar White, in that it scatters most of the solar spectrum just as white paint does for the visible. Our modeling of these coatings has shown that temperatures as low as 50 K can be reached for a coated object fully exposed to sunlight at 1 AU from the Sun and far from the Earth. In the second half of the report we explore a mission application of this coating in order to show that it allows LOX to be carried on a mission to Mars. Heat can reach a LOX tank in five ways: direct radiation from the Sun, scattered or reflected radiation from the Sun off of spacecraft components, radiation from nearby planets or the Moon, radiation from the infrared emission of other parts of the spacecraft, and conduction along support struts and flow lines. We discuss these and sum their total contribution when using a Solar White coating to demonstrate an architecture that allows the transportation of LOX to Mars. After this, other applications of Solar White are listed.

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



Technology Areas

Primary:

- TX14 Thermal Management Systems
  └ TX14.1 Cryogenic Systems
    └ TX14.1.1 In-space Propellant Storage & Utilization

Target Destination

The Sun